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Technological Change from Inside

A review of *Breakthroughs!*

Ashoka Mody

The reviewer gives high marks to *Breakthroughs!*, a book describing the way individuals conceived and developed new products and services, and then set about bringing them to market.

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Remember life before Post-its? You probably used scotch tape (made by 3M) to paste your note where you wanted it. What about putting the paste on the paper? If you were working at 3M, say, would it occur to you?

In Breakthroughs!, the authors detail the development of Post-it Note Pads and other products and services that have come to be regarded as indispensable (how did we ever do without them?) These products now seem ordinary. In many cases the technology was readily available. But what counts, the book says, is the con- cept, and even then, the route to commercial success requires considerable ingenuity and corporate support. Who were these innovators and what problems did they have to tackle before the market applauded their breakthrough?

The book presents case studies of 12 products and services; five consumer durables (cars, VCRs, Walkmans, microwave ovens, Nike athletic shoes); three services (Federal Express, Chem Lawn, Nautilus); two health care items (Cat Scans, Tagamet); an intermediate product (polyethylene); and the Post-it Note Pads.

While the authors applaud the tenacity and vision of the individual, they give some of the credit to the firms' marketing and manufacturing expertise. Ironically, the reviewer says, there isn't much concern for economic principles. Amana officials priced the microwave oven at $499 because they concluded that "It's about the same size as an air conditioner. It weighs about the same. It should sell for the same."

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Technological Change from Inside

A Review of *Breakthroughs!*
by P. Ranganath Nayak and John M. Ketteringham
Rawson Associates, New York, 1986

Ashoka Mody

TECHNOLOGICAL CHANGE FROM INSIDE

This is a book about products and services that have come to be regarded as indispensable (how did we ever do without them?)--Post-it note pads, microwave ovens, videocassette recorders, Federal Express (overnight mail). These ubiquitous products seem ordinary but the authors tell a fascinating tale of the ingenuity that produced them. The technology, in some cases, was commonly available. But it needed the imagination of specific individuals to define the new product; efficient organization to bring together diverse elements for its production; and both talent and teamwork were needed to effectively present the product. Without this delicate and indeterminate series of events, the authors contend, the product or service might never have materialized!

Though the title is a somewhat dramatic Breakthroughs!, the book is not about fundamental research or the development of seminal technologies. Rather, it is about incremental additions to knowledge, that in moments of inspiration add up to new products and services.

The virtue of the book is that it goes inside the firm, beyond the research laboratory and the mind of the innovator, to bring to life the world of marketing and manufacturing. Indeed, its major achievement is that it demonstrates the intimate links among research, manufacturing, and marketing.

The book presents case studies of 12 products and services: four consumer durables (VCRs, Walkmans, microwave ovens, Nike sports shoes); three services (Federal Express, Chem Lawn, Nautilus); two inputs to the health care industry (CAT Scans, Tagamet); an office and home stationery product (sticky note pads); an intermediate product (plastics); and, automobiles; described from the perspective of manufacturing efficiency rather than product conception and development.

The book emphasizes the changing role of individuals and organizations in bringing a product or service from initial concept to market. The individual provides the key idea--the breakthrough. The organization implements the idea. A flexible organization can turn whimsy into profit. The interaction between the individual and the organization is vividly described in a number of cases, including the chapter on Toyota, but the discussion on sticky note pads is particularly instructive.

The name 3M is famous for efficient R&D. The company emphasizes continuous improvement of existing product lines. Its scientists and engineers, like many of their Japanese counterparts, spend a lot of time improving product functionality and developing superior manufacturing techniques.

In 1964 a team of researchers at 3M began to explore a group of polymers. This was an applied research project without an immediate

product in mind. Researchers anticipated, though, that the work would lead to better adhesives for commercial tapes.

One of the group, Spencer Silver, was working on a newly discovered group of monomers that he thought had potential for polymer-based adhesives. Silver took advantage of the '15 percent rule' that permits 3M scientists to spend 15 percent of their time on research problems unrelated to the company's bottom line. Silver performed an experiment that violated the received methodology. He did not have any expectations from the experiment. It just seemed an interesting, if possibly bizarre, approach. The result was an adhesive that did not stick very well. The conventional wisdom was that adhesives were not of much use if they did not stick firmly and forever.

The effort that began in 1964 did not emerge as a product until the mid-1970s. Silver had to work hard to sell his idea to the company. Another colleague, Arthur Fry, in a moment of inspiration, had to come up with a product that used the adhesive. The role of the organization was to refine the strange adhesive, manufacture it, and convince the world that the product filled a need.

It is often noted that technological change is incremental, but that these increments add up to substantial progress. What is rarely discussed is the mechanism for sustaining the momentum in a particular direction. Is it the case, for example, that each increment occurs independently of what has occurred in the past? In other words,

is the process purely random? Or are there systematic intertemporal links? If so, are they embodied in particular individuals? Or is there an institutional history that drives the innovation process?

These are difficult questions. The book has a bias toward the individual. In describing the evolution and introduction of athletic shoes, the authors report on the long-drawn-out and single-minded efforts of Bill Bowerman, the designer of Nike sports shoes:

> 'By the mid-1970s, when Nike was still a small shoe company, four elements had become basic in athletic shoes. Bowerman had introduced them all. There had been, in his mind, a whole--an elegantly composed concept--almost as long as he had been a coach and teacher. But it had taken him more than twenty years to gather the resources and technical skills to synthesize them into one shoe.'

While this is the main theme, the book cites some instances when institutional memories played an important role. Kenjiro Takayanagi, a pioneer in the development of television technology at the Victor Corporation of Japan (JVC), foresaw the market for videocassette recorders (VCRs). He 'shared this dream' with a number of young researchers at JVC in the 1950s, and although he did not undertake the research himself, he was a guiding spirit and source of support when technological problems and external competition threatened to overwhelm the then-tiny company.

A typical problem with new products has been the determination of price and the potential market. A key step in the introducing

the microwave oven to the American consumer was the assessment by George Foerstner, the manager and founder of Amana Refrigeration: 'It's about the same size as an air conditioner. It weighs about the same. It should sell for the same. So we'll price it at $499.' Should this be considered an example of good pricing? There are similar incidents in other chapters. In the case of the microwave oven, Foerstner had to go one step further. He hired a railroad coach that for days 'traveled through the vast suburban sprawl that fans out westward from Chicago. At each stop, throngs of heavily recruited housewives were ushered onto the train and regaled with cooking demonstrations, food and drink, and homespun Amana, Iowa joie de vivre.'

Demonstrations of usefulness were even essential for the sticky note pads, strange as it seems. Conventional marketing techniques concluded that the sticky pad was a dead-end product. But for the enthusiasm of Geoffrey Nicholson and George Ramey, the product might have died a quiet death. After several conventional market tests had declared the Post-it pad was a non-starter, Nicholson and Ramey took the product to the firm's offices in Richmond, Virginia, and literally gave it away. They gambled that addiction would set in only after people could stick and re-stick the paper on 'desks, phones, books, labels, faces.' The day in Richmond provided them the 'vivid assurance' that the market studies had failed to uncover.

In the case of Tagamet, a drug for ulcers, pharmaceutical firms assumed that the total market for a new ulcer drug was limited to

converts from antacids. Unlike antacids, which provide protection against acid secretion by coating the stomach lining, Tagamet controls the degree to which acid is secreted. '... many at Smith, & Kline, French, (the producer of Tagamet) shared an intuition that there were more people in the world coping with ulcers than antacid sales, hospital admissions, or prescription totals had revealed.' Thomas Collins, the head of Tagemet's American marketing effort, had 'a vision of patients "coming out of the woodwork."' His vision was critical in planning the eventual capacity of the Tagamet manufacturing plant.

In the chapter on microwaves the authors discuss a decision to acquire technology from another firm. In 1949 Raytheon patented the first microwave oven. But for many years only large establishments, such as hotels, could afford microwaves. To bring the oven into consumers' homes, the oven had to be smaller and less expensive. That, in turn, required reducing the size of the magnetron. Despite the technical brilliance of the scientists at Raytheon who had discovered the microwave, miniaturization proved to be an insurmountable problem. In 1960 Raytheon bought an interest in the New Japan Radio Company (NJRC), a consumer electronics firm. There, after four years of research, Keishi Ogura solved the problem. Raytheon bought only a small number of magnetrons from NJRC, reverse engineered them, and then went into production at its plant in Waltham. There was no other technological link between the two companies: it was as though Raytheon had bought NJRC for the specific purpose of miniaturizing the magnetron. Raytheon had to go one step further and buy Amana Refrigeration, Inc. to market the oven. 'Amana provided the military contractor (Raytheon) an intimate familiarity with consumer attitudes and a distribution capability foreign to Raytheon. ... culturally, these were two very strange bedfellows.'

Not much is known about how particular firms develop particular capabilities. Nor is there much literature on how complementarities between firms can be exploited. The microwave oven story is an example of partially successful exploitation of complementarities. Success was only partial because by the early 1980s no American firm was

producing magnetrons. Even NJRC had lost ground to other competitors. Major Japanese and Korean consumer electronics firms had cut magnetron prices to levels that U.S. firms were unable to match. Thus, microwave oven technology, which originated in Britain and was incorporated into a consumer product in the United States was passed to East Asia.

A similar tale of technological leads and lags, of competition and cooperation, emerges from the case study of polypropylene, a colorless plastic produced at the rate of 14 billion pounds a year and used in virtually all those products that 'smooth the flow of our daily routine.'

Polypropylene was discovered by Giulio Natta in 1954 at the Milan Polytechnic Institute. Natta was hired by Montecatini which merged in 1966 with the Italian utility company, Edison, to become Montedison. He shared the Nobel Prize in Chemistry in 1963. At about the same time a number of Japanese companies were becoming interested in the potential of plastics. Many of them licensed the Montecatini technology and set to work on cheaper, more energy efficient methods of manufacturing the plastic. Mitsui Petrochemical Company, however, decided to develop the technology independently. Meanwhile, at Montedison, the technology languished and the firm was soon in a position where it had to license some elements of the manufacturing technology from the very firms to which it had earlier sold its basic patent. In the early 1970s there was some revival at Montedison's research laboratories (despite hostility from corporate headquarters).

Scientists there developed a new generation of manufacturing processes for polyethylene, a plastic with properties somewhat inferior to that of polypropylene. By one of those rare coincidences, a similar process was perfected at Mitsui petrochemical's laboratories almost simultaneously. After a long and bitter patent, dispute Montedison ultimately won the case.

In 1975 as both companies were about to develop a similar process for polypropylene, two scientists paved the way for a spectacular collaboration. Yasuji Torii, of Mitsui Petrochemicals, and Italo Trapasso, of Montedison, had known and admired each other for some time. They were familiar with each other's research. Neither was looking forward to a long patent battle. Both knew that the next effort would change the complexion of the industry and that when it happened, there would be 'enough to go around.' They agreed to jointly develop the plastic. The authors note that both companies have been successful in exploiting the technology, although in the case of Montedison (which is the only one discussed in detail), critical decisions in terms of scale, manufacturing location, and a strategic alliance were necessary.

Even the fiercely competitive market for videocassette recorders has a history of complex links between contenders. The first of these was formed when the 3/4-inch VCR seemed imminent. Matsushita, Sony, and JVC held a meeting at a trade show in Osaka:

> Although the representatives of all three companies treated the meeting as happenstance, it was, in fact, long-awaited and

> carefully orchestrated. Japanese electronics companies, although they are intensely competitive, maintain an informal network of communication about the progress of each other's new product research."

The three agreed to pool their knowledge so that the 3/4-inch VCR could be brought to the market more quickly. They decided to pool research efforts to improve Sony's design for the magnetic tape cassette, and agreed to cross-license each other's technical innovations. "None of the three companies would have to pay to use another's VCR-related patents. Also understood as part of the cross-licensing agreement was a sharing of future innovation." While the cross-licensing agreement was retained, actual research collaboration was soon stopped as competition once more become the major consideration.

A further collaboration was needed to make the JVC-designed format the industry standard. Shizuo Takano of JVC, one of the guiding spirits behind the VCR, said: "Our basic policy was to spread the information as well as spread the technology and the format. The market is large enough to hold everybody, so we don't have to worry about that." Takano and Yuma Shiraishi went on the road to demonstrate the equipment and explain the technology. They emphasized the importance of an industry standard and signed liberal licensing agreements to induce industry heavyweights, such as Hitachi and Matsushita, to use the JVC format.

The authors highlight the role manufacturing capability plays in exploiting a firm's technological advantage. Godfrey Hounsfeld, the inventor of the CAT Scan (for which he won the Nobel Prize) was also its first producer at the research laboratories of EMI, Ltd. in England. But EMI needed a large manufacturing facility to capitalize on the growing world market for medical equipment. The firm began building a plant in the United States. Construction, however, lagged, there was a recession, President Carter's administration pushed for cost containment in the medical industry, and EMI's pockets were not deep enough. The baton passed to others.

The most dramatic manufacturing story is Toyota's. An army of scholars has dissected the Toyota manufacturing philosophy and readers will wonder if this book contains any new information. What it provides are fresh insights into the stellar role played by individuals in a firm known more for its faultless organization. In this case it is the role of the integrator who sees the various parts and pieces them together.

Toyota introduced three concepts: just-in-time delivery (organizing the production flow so that no inventory builds up along the production line), kanban ("an information carrying device," which moves backward along the production line signaling when to move the work forward) and 'quality circles'. Even though the virtues of just-in-time are well known, it is sometimes forgotten that the concept was developed almost half a century ago in rural Japan by industrial engineers who had

little, if any, exposure to modern methods of factory management and operations research techniques. For decades afterwards, Western researchers continued to develop models to minimize inventory, never quite daring to suggest the idea of zero inventory. The difference between a small inventory and no inventory is profound because it signals a completely different method of production. It implies, moreover, a different value to engineers and shop-floor workers, and a different attitude to hierarchy and worker education. Sakichi Toyoda, father of the Toyota group of enterprises, 'incorporated his faith in the worker into the atmosphere of Toyoda Automatic Loom Works. ... He established the Toyota tradition of finding the best minds in the work force and keeping them as long as possible "on the shop floor," where they could examine the way things are done and think of ways to make them better.' This attitude is almost unique to the Japanese system. In most developing countries and even in the United States, creativity is not particularly sought from the shop floor. The incentive structure offers little to the bright young engineers who are interested in production techniques.

Taiichi Ohno is described as Toyota's "interpreter." He pieced together the concepts that emerged at different times and places in the Toyota group of companies. His guiding principle corresponded to that of Toyota's founder: use human intelligence. At a time when automatic equipment was increasingly common in automotive assembly operations. Ohno made the simple observation that such machines can automatically and continuously produce bad products whenever there is a

misalignment or machine failure. To prevent such loss, he introduced the concept of jikoda. This approach placed a premium on worker dexterity and intelligence. 'He wanted all workers to learn every function. He gave every worker the responsibility to halt the entire production line whenever the worker saw a problem, small or large, that could become worse if not corrected immediately.'

With the availability of modern methods of communication and "intelligent" machines, will this obsessive concern with worker intelligence become obsolete? Not in the near future. There are a plethora of intelligent machines available but they have to be sensibly deployed. They have to "talk" to other machines. Unless the production process is well understood, the probability of mismatch is very high. It should, therefore, be no surprise that the Japanese have had better success than others in introducing modern technology to the shop floor.

One of the current issues in methodology is the bias in the economics profession against the case-study methods. Statistical analysis (econometrics), in contrast, is scientific. This book demonstrates (if such a demonstration were needed) the rigor and value of case studies. There are at least three reasons why case studies may be superior to statistical analysis. First, in most econometric work there is an unexplained residual. In fact, very respectable articles have "explanatory powers" of 10 to 20 percent. Case studies, by their very nature, fill in seemingly minute and irrelevant details. They do not have statistical authority but they are more complete and can offer

plausible hypotheses. The results of case studies are also probably more robust, particularly when it is remembered that the addition or deletion of a few observations or a change in functional forms in econometrics often lead to drastically different conclusions.

Second, case studies lend themselves more easily to a description and analysis of process dynamics. In a descriptive format it is easier to trace the history of change. The large and growing literature on game theory, with its ubiquitous multiple equilibria, and the industrial organization literature, with its focus on sunk costs, has emphasized once more the importance of history. The reason case studies allow a better description is that they blend the quantitative with the qualitative and they have a built-in bias toward detail.

Finally, case studies highlight the role of accidents. Recent work by Brian Arthur and Paul David on the role of small perturbations in nonlinear dynamic systems emphasizes that historical accidents are crucial in determining the path taken by a system. The first meeting and ensuing friendship between Trapasso and Torii was just such an accident. If they had not met when they did, would they have agreed to collaborate; would the international plastics industry have been the same?

Few such micro studies have been done for firms and products in developing countries. The authors considered but could not

ultimately include Reliance Textiles of India. While we await such studies, can we learn something from the rich analysis of firm behavior and growth presented in 'Breakthrough!" The products described in this book have been spectacular. It is unlikely that firms in developing countries will be in a position to create such products, but the lessons of successful product innovation are relevant. Firms in developing countries can create new products to fill needs that are specific to the markets in which they operate. They can adapt existing products when locally available inputs differ from those available internationally. In either case, the process of innovation is similar, though scaled down. Fostering such a capability is not necessarily easy. It requires a competitive external environment and an appropriate product development structure within the firm. It requires, in particular, an emphasis on applied research (as distinct from basic research), which is not very common in developing country companies.

The book underlines the importance of delicate and finely timed links between firms. It points to the importance of bringing complementary capabilities together in the process of innovation. These links can take the form of effective industry associations, industrial extension centers, informal networks of engineers, formal joint ventures, loosely structured links between firms, and so on. The groups may be domestic or may include foreign firms. It is typically the case that such links are easier to form in expanding markets when rival concerns do not feel as threatened by sharing technology. To be

included, however, each participant has to bring something to the table. In other words, strong quid pro quos are expected.

In addition, manufacturing skills are critical. Although there is some literature on learning by doing, there is very little understanding of the process by which shop-floor productivity is increased. The Japanese have provided some insights into the process by emphasizing working in teams, multiple skills, greater independence and responsibility for production workers, and closer interaction between employees and engineers. Above all, they have placed a great social value on the engineering profession. While message has spread far and w. `, these features have not been easy to implement, particularly where established attitudes are strongly embedded. It should be remembered, though, that the Japanese took several decades to improve the quality of their manufactures, and if there is a lesson to be learned, persistence is certainly an important one.

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